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Influence of Antitranspirants¹ on Water Use, Growth Characteristics, and Relative Drought Resistance of Ponderosa Pine Seedlings

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Physiology

Antitranspirant

Ponderosa pine seedlings were treated with foliar sprays of Cycocel, hexadecanol, and Foli-gard at age 2 months, and were grown under favorable conditions in a controlled environment chamber. Cycocel significantly improved water use efficiency when soil moisture was optimal, but had no effect when moisture was limiting. In certain instances, height growth was stimulated by the hexadecanol and Foli-gard treatments. Limiting soil moisture alone produced greater resistance to moisture loss than any of the antitranspirant treatments.

In the Southwest, spring-planted ponderosa pines (*Pinus ponderosa* Laws.) are confronted with an annual spring drought lasting 2 months or longer. During this period, lack of adequate moisture and excessive transpiration create water stresses within the seedlings that limit survival and growth. A possible way to alleviate these stresses is to reduce transpiration with antitranspirants.

¹Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.

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According to Gale and Hagan (1966), antitranspirants may be classified as materials that: (1) cause stomatal closure, (2) form thin films, (3) form thick films, or (4) retard growth or reflect light. Thick surface films tried on conifers have generally produced inconsistent results (Shirley and Mueli 1938, Thames 1961). Failures with these heavy, wax-based foliage coatings are attributable to an unfavorable upset of the heat balance in needles (Thames 1961), and to interference with plant mineral nutrition (Gale and Hagan 1966).

In recent years, long-chain alcohols such as hexadecanol, which form a monomolecular film on the leaf surface, have been tested. This film is highly impermeable to water vapor. Stoeckeler (1966) applied hexadecanol as a foliage dip to red pine (*Pinus resinosa* Ait.) seedlings prior to planting on a droughty site, and reported an 18.4-percent gain

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in survival of treated seedlings. He found no difference in first-year survival on a more favorable site.

Foli-gard, a water-soluble polymer that forms a thin, clear, flexible film on foliage, was tested on planted Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings (Roy 1966.) Although the treatment did not affect seedling survival, mean height of treated seedlings was significantly greater.

Certain growth retardants such as phosfon and Cycocel have been reported to reduce plant water stress and the transpiration/growth ratio (total transpiration divided by total dry matter production) (Goodin et al. 1966, Halevy and Kessler 1963). Plants treated with Cycocel reportedly require less water, are more resistant to wilt (Halevy and Kessler 1963), heat (Cathey 1962), salt (Marth and Frank 1961), and frost (Marth 1965).

This experiment was designed to evaluate the effects of hexadecanol,³ Foli-gard,⁴ and Cycocel⁵ on growth, transpiration, and drought resistance of young ponderosa pines grown under two moisture regimes in a controlled environment chamber.

Materials and Methods

The experiment was conducted in two concurrent phases; each phase consisted of 32 pots that contained 12 seedlings each. The experimental design was a 4x2 factorial (three antitranspirants + control x two soil moisture levels) arranged in a completely randomized design with four replications. In phase A, the objectives were to determine the effects of antitranspirants on water use and growth characteristics; in phase B the effects upon relative drought resistance and the capacity of the seedlings to resist moisture loss were evaluated.

Metal pots, 4.5 inches in diameter by 12 inches high, were filled with equal weights of screened, air-dry forest soil (a silt loam derived from limestone, A horizon, 0-6 inches). The soil surface was

covered with a thin layer of Perlite to lessen evaporation and damping-off. Each pot was planted with 12 newly germinated ponderosa pine seedlings, which were then raised in a growth chamber under a constant optimum temperature of 23° C. (Larson 1967) and 16-hour photoperiod for 58 days. The antitranspirants tested, as aqueous foliar sprays, were:

	Percent in water	Number of applications
Hexadecanol	1	1
Foli-gard	20	1
Cycocel + Tween 40 ⁶	0.25+0.025	4, biweekly

Two regimes of soil moisture, 10-15 and 25-30 percent of oven-dry weight, designated as "low" and "high" soil moisture, respectively, were begun concurrently with the antitranspirant treatments. Soil moisture was maintained within these ranges by pot weight, and water use was recorded. Concurrently, evaporative water loss from eight pots without seedlings was recorded to determine the weight of water transpired. Four accessory pots of seedlings were harvested at 58 days so that mean seedling dry matter production during the 82-day period following treatment could be determined. After 140 days, foliage height (distance from cotyledons to shoot tip) and dry weight of tops and roots were determined. Data on foliage height, mean top dry weight, mean root dry weight, top/root ratio, mean dry matter production, mean transpiration per seedling (after treatment), and transpiration/growth ratio were analyzed by analysis of variance.

After phase A was terminated, seedling resistance to moisture loss and relative drought resistance were tested with the identically treated phase B seedlings. The seedlings were watered to their designated soil moisture level the day before the drought tests began. Then each pot of seedlings was thinned so that at least two seedlings were removed from each pot, and all pots contained the same

³ADOL 52-NF was supplied by the Archer Daniels Midland Company.

⁴Rutex Foli-gard is manufactured by the UBS Chemical Company.

⁵Cycocel, technical grade (98 percent active ingredient) was furnished by the American Cyanamid Company.

⁶Tween 40 was used in preference to Tween 20 because of its lack of biological activity (Vieitez et al. 1965).

number of seedlings. The two seedlings removed from each pot were tested for their capacity to resist moisture loss (Sullivan and Levitt 1959) by determining the decline in foliage moisture content (FMC, percent moisture content based on oven-dry weight). The residual seedlings were subjected to an artificial drought; relative drought resistance was determined by rewatering one pot from each treatment combination after 10, 20, 30, and 40 days without water.

Results and Discussion

Phase A

Table 1 presents the mean foliage height, mean top and root dry weight, and top/root ratio for each of the treatments under both soil moisture levels. The effects of the antitranspirants and soil moisture on transpiration per seedling, dry matter production, and transpiration/growth ratio are presented in table 2. All growth and moisture-use values for seedlings grown with high soil moisture were significantly greater than those for low soil moisture except the top/root ratio, which was significantly higher for seedlings grown under low soil moisture. This result disagrees with the findings of Steinbrenner and Rediske (1964), who reported that high soil moisture increased the top/root ratio. The difference is traceable to the effects on root weight. Steinbrenner and Rediske found little difference in root weight between high and low soil moisture, whereas in the present study high soil moisture increased root weight.

Cycocel did not affect foliage height or dry weight significantly. With high soil moisture, Cycocel significantly reduced transpiration per seedling and the transpiration/growth ratio, which implies improved water use efficiency. Under low soil moisture, however, where efficient water use may be critical, the Cycocel-treated seedlings did not differ significantly from the control seedlings.

Hexadecanol had no significant effects on water use. Although treatment with hexadecanol with high soil moisture significantly increased foliage height, the actual increase was small and may not be of practical importance. Under low soil moisture, stimulation of height growth was probably overcome by the growth-suppressing influence of water

stress. Abdalla and Flocker (1963) and Roberts and Lage (1965) report large increases in weight of treated plants. Long-chain primary alcohols with plant-growth-promoting activity have been isolated from Maryland mammoth tobacco (Vlitos and Crosby 1959). Hexadecanol is more commonly reported to reduce plant growth than to stimulate it, however.

Foli-gard increased the height of treated seedlings significantly under the low soil moisture regime. The greater height growth was accompanied by moderate, but not significantly greater, top dry weight. There were no significant effects on the top/root ratio. Similarly, in work with Douglas-fir, Roy (1966) found that treatment did not affect seedling survival, but apparently promoted height growth. Treatment with Foli-gard did not affect water use.

Phase B

The FMC critical for survival of ponderosa pine seedlings is approximately 100 percent,⁷ but this value depends on the exact nature of the desiccating environment. Below this critical value, the effects of the antitranspirants on FMC have little meaning in terms of seedling survival from drought. Treatment differences in resistance to moisture loss were therefore evaluated in terms of the time to reach 100 percent FMC (fig. 1).

At the time the seedlings were severed there was no difference in FMC between the two soil moisture levels. After they were severed, however, seedlings grown under low soil moisture required significantly more time to reach 100 percent FMC. The actual difference was 1.4 days. This implies that soil moisture pretreatment had some effect on seedling resistance to loss of moisture.

The antitranspirants influenced the rate of desiccation, but not in a fashion that would improve survival. When the seedlings were severed (day 0), the Cycocel-treated plants grown under both levels of soil moisture had a higher FMC than the controls,

⁷Personal communication with Dr. M. M. Larson, Ohio Agricultural Research and Development Center, Wooster, Ohio.

Table 1.--Effects of antitranspirants and soil moisture on growth characteristics of ponderosa pine seedlings (values listed are treatment means)

Treatment	Foliage height		Mean top dry weight		Mean root dry weight		Top/root ratio	
	High	Low	High	Low	High	Low	High	Low
	<u>Inches</u>		- - - -		<u>Grams</u>		- - - -	
Cycocel	1.15	0.80	0.69	0.52	0.49	0.21	1.41	2.48
Hexadecanol	1.35**	.86	.90	.53	.39	.15	2.31	3.53
Foli-gard	1.25	.97*	.90	.62	.30	.20	3.00	3.10
Control	1.14	.82	.77	.51	.40	.18	1.93	2.83

* Significantly different from control at the 5 percent level.

** Significantly different from control at the 1 percent level.

Table 2.--Effects of antitranspirants and soil moisture on water use by ponderosa pine seedlings (values listed are treatment means)

Treatment	Transpiration per seedling (water)		Dry matter production ¹		Transpiration/growth ratio	
	High	Low	High	Low	High	Low
	- - - -		<u>Grams</u>		- - - -	
Cycocel	352.6**	215.0	0.96	0.51	367.3*	421.6
Hexadecanol	448.5	220.9	1.07	.47	419.2	470.6
Foli-gard	457.5	232.9	.98	.59	466.8	394.8
Control	465.9	210.3	.94	.47	495.6	447.5

¹Dry matter formed during the 82 days following treatment.

* Significantly different from control at the 5 percent level.

** Significantly different from control at the 1 percent level.

as did the hexadecanol-treated plants under low soil moisture. During the desiccation period, these treated seedlings exhibited lower FMC than the controls and required significantly fewer days to reach 100 percent FMC (fig. 1). Thus, the Cycocel and hexadecanol treatments apparently lowered seedling resistance to moisture loss. Low soil moisture pretreatment had a greater effect on resistance

to moisture loss of severed seedling tops than did any of the antitranspirants.

The test for relative drought resistance was unsuccessful because most of the seedlings recovered. Some seedlings died after 40 days of drought, but the results were inconclusive. During the drought test, the soil moisture content dropped 1 to 2 percent below the 15-atmosphere moisture percentage.

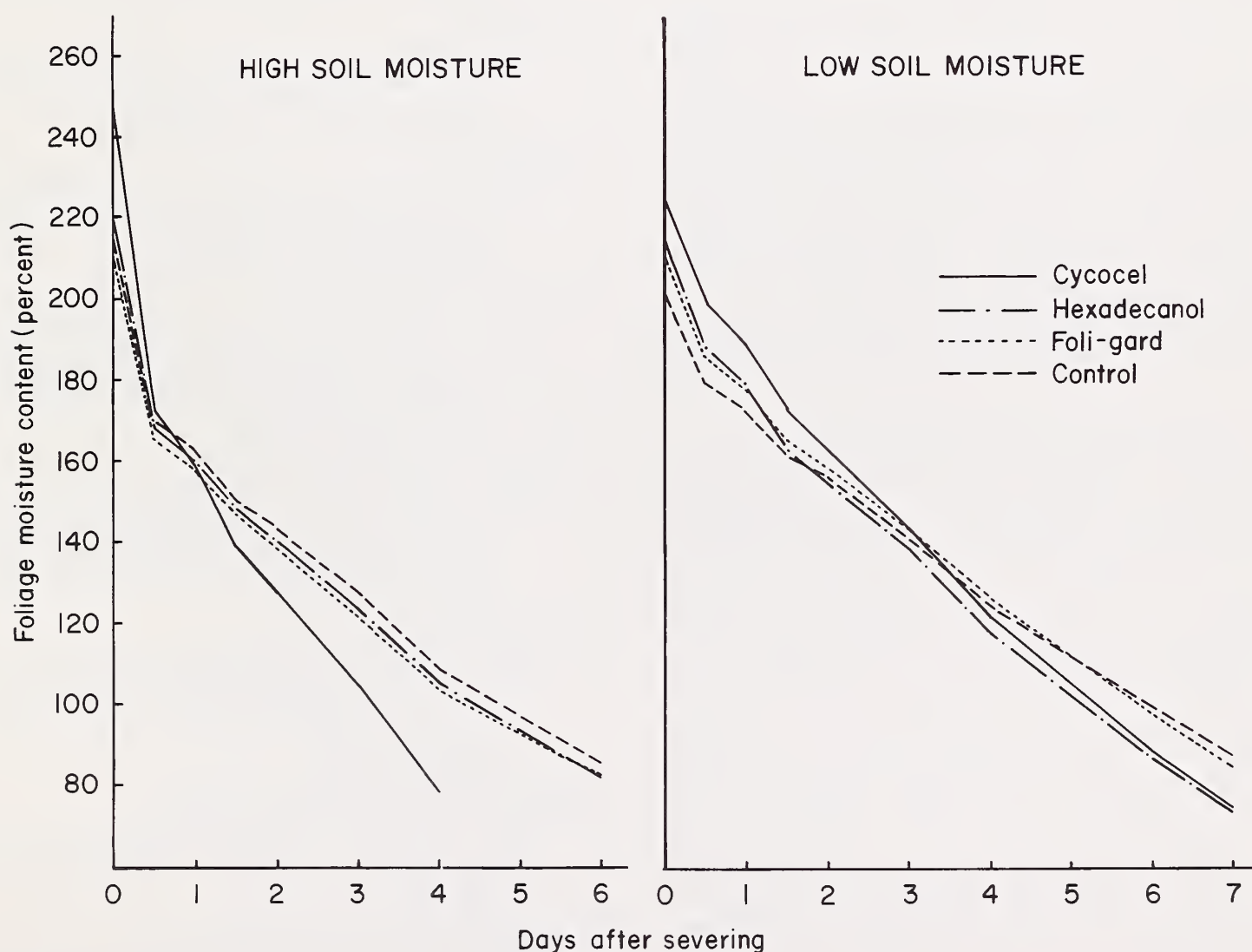


Figure 1.--Foliage moisture content (FMC) of severed tops of treated seedlings during a desiccation period in the growth chamber. Each line represents the average of eight seedlings.

Summary and Conclusions

Principal results of the study are:

1. Seedlings grown under high soil moisture (25-30 percent of oven-dry weight) grew taller and heavier, had a lower top/root ratio, and used more water with less efficiency than seedlings grown under low soil moisture (10-15 percent of oven-dry weight).
2. Treatment with Cycocel reduced transpiration and therefore increased water-use efficiency only in seedlings grown under high soil moisture. Hexadecanol stimulated height growth in seedlings grown under high soil moisture, whereas Foli-gard stimulated height growth only in seedlings grown under low soil moisture.
3. Seedlings grown under low soil moisture lost moisture more slowly after they were severed than seedlings grown under high soil moisture. Seedlings treated with Cycocel or hexadecanol maintained a higher FMC than the controls while growing under low soil moisture, but lost moisture more rapidly than the controls when severed from their root systems. Foli-gard had no effect on seedling resistance to moisture loss.
4. The tests of antitranspirants and soil moisture on relative drought resistance were inconclusive.

The following conclusions can be drawn:

1. Low soil moisture alone enhanced seedling resistance to moisture loss more than any of the antitranspirant treatments. Under the conditions of the experiment, none of the antitranspirants had any effect on water economy under low soil moisture. Cycocel and hexadecanol apparently reduced seedling resistance to moisture loss. Therefore, it is doubtful if any of the antitranspirants as applied in this experiment would significantly improve seedling resistance to drought.
2. Both hexadecanol and Foli-gard significantly increased seedling growth. The actual differences in seedling height were small. Growth stimulation by hexadecanol appeared to be overcome by moisture stress, but stimulation by Foli-gard was not.

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